Studies on chemically synthesized mixed transition Metal Oxide electrodes for Electrochemical Energy Storage applications

Synopsis in candidature for degree of

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Introduction

In the present day situation, the green energy requirement is increasing day by day. The energy from fossil fuels is not convenient to use because it causes pollution and which ultimately results in increasing global warming [1]. In order to overcome such difficulties, we need energy from renewable energy sources such as solar, wind and hydro energy. The next problem is to store such energy efficiently for future use. There are a huge number of energy storage devices of which batteries and supercapacitors are the most promising electrochemical energy storage devices. The supercapacitors can now even replace the batteries completely because of their rapid charging, high power density and long cycle life. The supercapacitors have tremendous application areas for heavy-duty vehicles, hybrid platforms for trucks and buses, load-levelling systems for intermittent renewable energy sources, and storing the regenerative braking energy of electric vehicles and light rail. Batteries and fuel cells have higher energy density than that of the supercapacitors which limits its widespread use. Research efforts are underway with the goal of achieving the energy-storage capability of batteries without sacrificing their power density and cycling stability [2]. Supercapacitors provide high power density than conventional batteries and extraordinary energy density than conventional capacitors. Hence, they are emerging as an alternative energy storage device. Supercapacitors are attracted much attention for power backup systems, hybrid electric vehicles, and electronic components [3]. In the current market, commercial production of supercapacitors is based on the high surface area of electrode materials. Composites of Mixed Transitions Metal-oxide (MTMOs) have tremendous scope to provide such high surface area advanced electrodes for supercapacitors [4].

Literature review

The transition metal oxides (TMOs) of cobalt, tin, nickel, cobalt, manganese, and iron attracted as supercapacitor electrode due to their high power density and capacity for energy storage application [5]. Nevertheless, TMO electrodes in energy storage devices suffer from issues like poor electronic conductivity, primitive particle agglomeration, and volume change during electrochemical reactions [6]. These problems were addressed by various approaches like the development of TMO nanostructures and a combination of multiple conductive materials with TMOs [5]. The combination of TMO with graphene nanosheets significantly addressed issues of electrochemical reactions in LIBs and supercapacitors [7]. Graphene provides a highly conductive network through flexible supporting layer. It also effectively reduces particle agglomeration and volume change issues [8]. Besides graphene-based TMO, a combination of electrochemically active transition metals with TMO addresses the issue of volume change of electrode material [9].

Additional metal with TMO provides a mechanical buffer to reduce volume changes [10]. Hence, to solve issues of volume expansion and poor conductivity of TMO in energy storage devices, further new material research is directed toward the mixing of transition metals with TMO [5]. In consequence to these advantages, mixed transition metal oxides (MTMOs) draw more interest in development of electrodes for supercapacitors. To the best of our knowledge, there have been very few studies on the application of these MTMOs in Supercapacitor. Therefore, we will have synthesized MTMOs electrodes using one of the appropriate chemical methods for Supercapacitor device fabrication.

Aim;

In this proposed plan of work, our aim is to focus on the synthesis of mixed transition metal-oxides for supercapacitor application by using appropriate chemical route method. The main purpose behind this work is to enhance the energy density, power density, rate of cycle life in supercapacitor application.

Objectives:

The main objective of this synopsis to develop and synthesis MTMO's for high performance supercapacitor device fabrication.

- Synthesis of MTMO's electrodes such as $NiCo_2O_4$, $CuCo_2O_4$, $ZnCo_2O_4$ nanostructure using appropriate chemical synthesis methods.
- Structural and morphological properties of the prepared nanostructured electrodes will be studied using various characterization techniques such as X-ray diffraction (XRD), field emission scanning electron microscope (FE-SEM), high resolution transmission electron microscopy (HR-TEM), X-ray photoelectron spectroscopy (XPS), energy dispersive X-ray spectroscopy (EDS), Fourier Transform Infrared Spectroscopy (FTIR), Raman Spectroscopy, etc.
- Electrochemical performance will be studied in various electrolyte solutions with different molarity.
- Rate capability and capacitance retention will be studied.
- Symmetric/asymmetric device will be fabricated.

Methodology:

There are several methods in the literature for the synthesis of MTMO's such as SILAR, CBD, hydrothermal method, etc. which is reliable and easy to synthesis of MTMO's. Among these

following appropriate methods, one of the synthesis methods will be used to synthesized MTMO's.

1] SILAR: SILAR method is economically, highly feasible for large area deposition and wastage of chemicals can be avoided. For the deposition of material thin film, a well-cleaned glass substrate was immersed in the cationic precursor solution, causing cations to be adsorbed on the surface of the glass substrate. This substrate was immersed in an ample amount of double distilled water to prevent homogenous precipitation. The substrate was then immersed in the anionic precursor solution. Anions reacted with the adsorbed cations on the glass substrate. The substrate was then immersed in double-distilled water.

2] Chemical Bath Deposition: By optimizing CBD preparative parameters, such as deposition temperature, time, pH, complexing agent etc. Transition metal oxide films werepreprepared. The metal oxide films were deposited from the solution containing precursor by using different complexing agents.

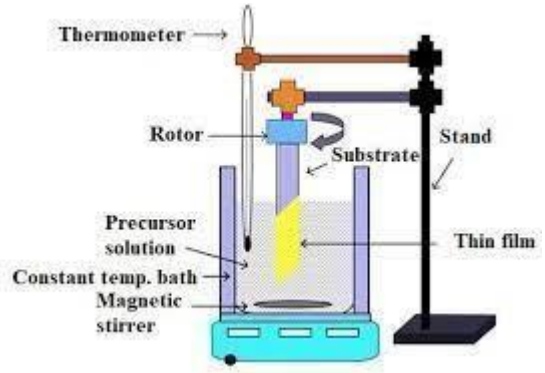

Fig. 2: Instrumentation details of CBD.

3] Hydrothermal Method:

Hydrodrothermal synthesis is a unique method for crystallizing substances from high-temperature aqueous solutions at high vapor pressures; also termed "hydrothermal method." The term "hydrothermal" is of geologic origin. Hydrothermal synthesis can be defined as a method of synthesis of single crystals that depends on the solubility of minerals in hot water under high pressure. The crystal growth is performed in an apparatus consisting of a steel pressure vessel called an autoclave in which a nutrient is supplied along with water. A temperature gradient is maintained between the opposite ends ofthe growth chamber. At the hotter end the nutrient solute dissolves, while at the cooler end it is deposited on a seed crystal, growing the desired crystal.

Characterization:

Synthesized MTMO's electrodes will be characterized by using different analytical tools and techniques such as X-ray diffraction (XRD), Raman spectroscopy, Fourier Transform Infrared Spectroscopy, Field Emission Scanning Electron Microscopy (FE-SEM), High Resolution Transmission Electron Microscopy (HR-TEM) X-ray photoelectron spectroscopy (XPS), energy dispersive X-ray spectroscopy (EDS), etc.

Electrochemical workstation will be used to study the electrochemical properties and device fabrication such as cyclic voltammetry (CV), Galvanostatic charge-discharge (GCD), stability, rate capability, and impedance spectroscopy, etc. Finally, carried work will be submitted to the university for the award of Ph.D. in the form of thesis.

The proposed work will be carried out in following phases:

Phase – I (First Year)

- In the first year, literature survey will be carried out. The various MTMO's will be prepared using suitable synthesis method.

Phase – II (Second Year)

- The electrochemical performance of the prepared MTMO's will be measured and studied in different electrolyte such as KOH, H_2SO_4, NaOH, KCL, etc.

Phase – III (Third Year)

- To the study the industrial potential of the prepared MTMO's, the symmetric /asymmetric device will be fabricated.
- The work will be communicated time to time with the high impact journals.

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